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ABSTRACT

The use of general systems theory in the field of instructional systems design (ISD) is explored in this paper. Drawing on work by Young, the writings of 12 representative ISD writers and researchers were surveyed to determine the use of 60 general systems theory concepts by the individual authors. The average number of concepts used by these authors was found to be 18, which included an average of 9.6 of the Group 1 concepts identified by Young (systemic and descriptive factors). A second matrix which showed authors ranked by highest to lowest usage of the concepts indicated that the following 14 concepts were used by 10 or more authors: system, learning, objective, field, isolation and interaction, process, feedback, control, communication, change, boundaries and environment, integration and differentiation, input, and goal. It is suggested that instructional designers should be familiar with the relationship between the ISD field and other disciplines, and should have a working knowledge of basic terms, concepts, and applications of general systems theory. Finally, it is noted that ISD benefits from the use of terms that are more precisely defined in general systems theory than in common usage. The text is supplemented by eight figures and two matrices. (17 references and a 14-item bibliography) (EW)

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General Systems Theory and Instructional Design

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Paper presented at the annual meeting of the American Educational Research Association, New Orleans, April 1988

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General Systems Theory and Instructional Design

Introduction

The field of instructional systems design (ISD) bears a strong kinship to the field of general systems theory (GST). GST actually provided many of the basic concepts from which instructional systems models have been derived. Concepts such as feedback, goals, input, process, product, and output are terms with which instructional designers are well acquainted. However, there are many other important "systems" concepts with which instructional designers are not normally familiar. Some of these are: boundaries, channeling, entropic behavior, open systems, closed systems, homeostasis, equilibrium, negative entropy, system stress, overload, and steady state. The purpose of this paper is to (a) describe the basic concepts in the field of general systems theory, (b) identify the major commonalities that exist between GST and ISD, and (c) pin down the dimensions of GST that should prove most useful to the field of instructional design.

Origins of GST

Although the exact nature of the field covered by general systems theory is not completely clear or well-defined, the origin and development of the field is fairly well known. Back in the 50's and 60's a number of scientific researchers began an effort to emphasize and describe the commonalities which exist among various scientific disciplines. Their desire was to link together contributions from many fields which they felt had much in common.

To these researchers, the major commonality among these fields appeared to be the notion of a system. All of the fields dealt with systems in some way. General systems theory, therefore, was created as a means of studying these system commonalities. As Young (1964) points out, "It was felt that at a basic level all of the disciplines concerned must deal with systems of one kind or another and that there must be a goodly number of basic orienting concepts which are relevant to systems of all kinds" (p. 61). General systems theory then, is an interdisciplinary theory which consists of a set of concepts, constructs, facts, and terms which describe and explain the characteristics and phenomena associated with any system.

Like ISD, general systems theory is based on the belief that useful results can be obtained by combining and synthesizing contributions from many fields. ISD attempts to combine knowledge from such areas as cognitive psychology, behavioral psychology, management theory, instructional design theory, media research, and computer technology for the purpose of improving instruction. General systems theory draws

from a number of separate scientific disciplines to attempt to describe, explain, and predict the behavior of a general system.

GST Concepts

Young (1964) describes the following four categories of areas covered by GST terms (see Table 1): (a) systemic and descriptive factors, (b) factors dealing with the regulation and maintenance of systems, (c) factors dealing with dynamics and change within a system, and (d) factors dealing with decline and breakdown of systems. The wide spectrum of discussions in general systems theory can be categorized into one of these four areas.

Insert Table 1 About here

Developments in a wide variety of fields may be linked to general systems theory. For example, cybernetics (the study of feedback providing mechanisms for goal-seeking behavior), systems engineering (scientific planning, design, evaluation, and development of man-machine systems), operations research (scientific control of existing man-machine systems), human factors engineering (the matching of machine requirements with user capabilities), and instructional systems design (the use of systems models specifically oriented to the production of effective and replicable instructional programs). All of these fields represent the application of general systems concepts to specific areas of concern.

GST in the ISD Literature

Many general systems theory terms are used repeatedly in the ISD literature. Before looking at an empirical analysis of a sampling of this literature, let me make a few general observations. First, in the instructional design literature, there seems to be an emphasis on a few basic GST terms and a strict exclusion of other GST concepts. Specifically, the concepts of feedback, goals, input, process, product, and output are terms which are widely emphasized in the ISD literature. On the other hand, terms such as homeostasis, equilibrium, and entropy are seldom, if ever, mentioned. Secondly, there appears to be a tendency in the ISD literature to utilize GST concepts without discussing them thoroughly or defining them operationally. Thirdly, although GST terms are used throughout the ISD literature, general systems theory, per se, is never mentioned.

The first rudimentary steps in application of systems thinking is to simplify the elements of a complex system into its most basic components and describe (and, where possible, quantify) the interrelationships which may exist among those components. Therefore, the application of GST to a field usually results in some type of diagram or model (often in the form of a flowchart) which depict the specific elements of that particular system. One of the major accomplishments of the ISD field has been in the development of models and diagrams which depict system elements (see Figures 1-8). These models, flowcharts, graphs, formulas, measurements, and instruments are demonstrations of systems thinking.

Insert Figures 1 - 8 About Here

Which authors in ISD have been utilizing which GST concepts? In order to answer this question, I have surveyed the writing of a representative sample of ISD writers and researchers. The purpose of this survey was to identify aspects of GST on which ISD authors place emphasis. To show the results of my survey, I have constructed two matrices similar to Young (1964) which shows graphically which of the authors employ which GST concepts in their writings. Each matrix covers 60 concepts and 12 authors, and indicates the major areas of emphasis and de-emphasis of these writers as far as general systems concepts are concerned. The concepts are those listed by Young (1964). The 12 authors were selected from my own professional library and libraries of my immediate colleagues. I feel the selection of authors to be an adequate sampling of current ISD literature.

The first matrix lists the 60 concepts by group and demonstrates that there is an emphasis on Young's Group 1 terms. Of the 60 concepts shown in the matrix, the average number of concepts used by an author is 18. The average number of Group 1 concepts is 9.6. The matrix also shows the important role of the book by Borich in dealing with general systems concepts. Matrix 2 lists the 60 GST concepts and 12 authors in rank order from highest usage to lowest. This matrix reveals 14 concepts which are used by 10 or more authors. These are: system, learning, objective, field, isolation and interaction, process, feedback, control, communication, change, boundaries and environment, integration and differentiation, input, and goal.

Insert Matrices 1 and 2 About here

Conclusion

Instructional designers should be familiar with the larger picture of the ISD field, its fraternity with other related "systems" disciplines, and its kinship with general systems theory. The field of ISD is that branch of education which has most fully embraced systems concepts and thinking. ISD can properly be viewed as a field which has emerged as a result of the application of general systems theory to the specific problem of education. The Instructional design field has been able to accomplish most of what it has done because of our knowledge of systems—that is, because of our realization that all of the components of a system working together as a unit can accomplish more than could be done by all of the components operating individually. This is one of the basic tenets of general systems theory: the whole is greater than the sum of its parts.

Instructional designers who want to work with systems problems should have a working knowledge of basic GST terms, concepts, and applications. Several GST concepts are useful to us in describing, for example, why many of our innovations and interventions do not take hold in every case. In an excellent paper by Charlie Reigeluth (1983), he describes the following problem in dealing with improving the public schools:

> "...a basic tenent of systems theory is that, if you try to significantly change one part, the system will almost always work to change it back again." and, "...anything beyond fine-tuning of any system requires system-wide planning and modification" (pp. 4-5).

The phenomena Reigeluth alludes to in the above quotations are referred to in general systems terms as entropy and homeostasis. Entropy refers to the systems phenomenon that unless some continual source of energy is focused on an activity, energy within a system will dissipate and become random. According to the concept of entropy, the natural tendency of a system is to use its energy for non-systematic behavior. Homeostasis refers to the tendency for the forces within a system to counteract each other—the tendency of a system to move back to a previous state of equilibrium after being disturbed by forces external to the system. These concepts, then, are useful in helping us understand systems and their counteracting effects on our instructional innovations and interventions.

In addition to offering additional concepts and terms which are valuable to our understanding of systems phenomena, GST also provides better, more precise definitions of commonly used terms. Precise definitions and even mathematical equations are available for describing and quantifying positive and negative feedback within a system.

In addition, more precise categorizations of feedback have come from general systems theory, namely: goal-seeking feedback, goal-changing feedback, and amplification feedback. The field of instructional design could benefit from these more precise and better defined concepts.

There is value to be gained in recognizing the close ties between ISD and general systems theory. In the ISD field, we find ourselves dealing more with (or at least wanting to deal more with) systems problems and proposing system-wide solutions. It would be worthwhile, in my opinion, for us to realize that other fields (such as engineering) have advanced much farther than ourselves in describing, understanding, and predicting systems phenomena, and there is nothing to be gained by reinventing the wheel. I grant that in education we have serious complexities involved (in that we deal with human beings); but if we can gain a better understanding of how systems work in simple situations, we can then proceed step-by-step to understand how systems work in complex situations.

We should realize also, that we are already using many general systems concepts in our writing and in our work. But we can benefit by better defining and operationalizing our terms, and by extending our use of systems concepts to less understood (by us) general systems terms.

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Figure Captions

Figure 1. An early conceptualization of the systems approach to human resources development and training (from Branson & Grow, 1987).

Figure 2. The Dick and Carey systems approach model for designing instruction (from Dick & Carey, 1985).

Figure 3. The model of interservice procedures for instructional systems development (IPISD) (From Branson & Grow, 1987).

Figure 4. Information flow in short- and long-term memory systems (From Gagné & Glaser, 1987).

Figure 5. Banathy's description of an educational systems complex (From Banathy, 1987).

Figure 6. Some examples of inputs and processes in education (From Kaufman & Thiagarajan, 1987).

Figure 7. Kaufman's organizational elements model showing examples and their relation to organizational and societal results (From Kaufman & Thiagarajan, 1987).

Figure 8. The organizational elements model in its bi-level form showing gap between "what is" and "what should be" (From Kaufman & Thiagarajan, 1987).

Table 1. Four Categories of GST Concepts as Described by Young (1964)

1. **Systemic and Descriptive Factors**

   These concepts deal with types of systems, the internal organization of systems, and systems and their surroundings.

   1.1. open and closed systems
   1.2. organismic and non-organismic systems
   1.3. subsystems (general purpose)
   1.4. subsystem (special purpose)
   1.5. state-determined system
      1.5.1. state
   1.6. equifinality
   1.7. boundaries and environment
   1.8. field
   1.9. orders of interaction
   1.10. isolation and interaction
   1.11. interdependence and independence
   1.12. integration and differentiation
   1.13. centralization and decentralization
      1.13.1. centralized system
      1.13.2. leading part

2. **Regulation and maintenance**

   These concepts deal with the regulation, control, and stabilization of systems.

   2.1. stability
      2.1.1. ultrastable system
      2.1.2. multistable system
   2.2. equilibrium
      2.2.1. stable vs. unstable equilibrium
   2.3. feedback
      2.3.1. negative feedback
      2.3.2. positive feedback
      2.3.3. goal-seeking feedback
      2.3.4. goal-changing feedback
      2.3.5. amplification feedback
   2.4. homeostatasis and self-regulation
   2.5. steady-state maintenance
   2.6. control
   2.7. negative entropy
   2.8. repair and reproduction
   2.9. communication

3. **Dynamics and Change.**

   These concepts deal with problems of non-disruptive change, responses to altered environmental condition, and internally generated processes of change.

   3.1. adaptation
      3.1.1. goal-seeking feedback (see also 2.33)
      3.1.2. goal-changing feedback (see also 2.34)
      3.1.3. plasticity
      3.1.4. elasticity
   3.2. learning
   3.3. growth
      3.3.1. simple growth
      3.3.2. population growth
      3.3.3. structural growth
   3.4. change
      3.4.1. reversible change
      3.4.2. irreversible change
   3.5. teleology
   3.6. goal
   3.7. dynamism and dynamics

4. **Decline and Breakdown**

   These concepts deal with problems of disruption, dissolution, and breakdown in systems.

   4.1. stress
   4.2. disturbance
   4.3. overload
   4.4. positive entropy
   4.5. decay

Matrix 1. GST Concept Group/Author Matrix

		Group	Borich 1982	McCor. 1976	Smith 1966	Gagné 1962	Dick 1985	Heinich 1985	Gagné 1987	Brans. 1976	Reigelu 1983	Briggs 1977	Gagné/ Briggs 1974	Kemp 1985	Totals:
1	open and closed systems	1	1	1	1										3
2	organismic and non-organismic systems	1													0
3	system	1	1	1	1	1	1	1	1	1	1	1	1	1	12
4	subsystem	1	1	1		1			1			1			5
5	subsystems (general purpose)	1													0
6	subsystem (special purpose)	1													0
7	state-determined system	1													0
8	state	1													0
9	equifinality	1													0
10	boundaries and environment	1	1	1	1	1	1	1	1	1		1	1		10
11	field	1	1	1		1	1	1	1	1	1	1	1	1	11
12	orders of interaction	1	1												1
13	isolation and interaction	1	1	1	1	1	1	1	1	1	1	1		1	11
14	interdependence and independence	1	1	1						1			1		4
15	integration and differentiation	1	1	1	1	1	1	1	1		1		1	1	10
16	centralization and decentralization	1													0
17	centralized system	1													0
18	leading part	1													0
19	objective	1	1	1	1	1	1	1	1	1	1	1	1	1	12
20	input	1	1	1	1	1	1	1		1	1	1	1		10
21	process	1	1	1	1	1	1	1	1	1	1	1	1		11
22	output	1	1	1	1	1	1	1		1	1	1			9
23	product	1	1	1		1	1	1		1	1	1			8
24	stability	2													0
25	ultrastable system	2													0
26	multistable system	2													0
27	equilibrium	2			1										1
28	stable vs. unstable equilibrium	2													0
29	feedback	2		1	1	1	1	1	1	1	1	1	1	1	11
30	negative feedback	2													0
31	positive feedback	2													0
32	goal-seeking feedback	2													0
33	goal-changing feedback	2													0
34	amplification feedback	2													0
35	homeostasis and self-regulation	2			1										1
36	steady-state maintenance	2													0
37	control	2	1	1	1	1	1	1	1	1	1		1	1	11
38	negative entropy	2													0
39	repair and reproduction	2			1			1	1						3
40	communication	2	1	1	1	1	1	1	1	1	1	1	1		11
41	adaptation	3	1	1	1		1		1		1			1	7
42	plasticity	3													0
43	elasticity	3													0
44	learning	3	1	1	1	1	1	1	1	1	1	1	1	1	12
45	growth	3	1	1	1	1	1	1	1	1					8
46	simple growth	3													0
47	population growth	3													0
48	structural growth	3													0
49	change	3	1	1	1	1	1	1	1	1	1	1		1	11
50	reversible change	3													0
51	irreversible change	3													0
52	teleology	3													0
53	goal	3	1			1	1	1	1	1	1	1	1	1	10
54	dynamism and dynamics	3	1		1	1			1						4
55	isomorphism	3	1												1
56	stress	4		1	1	1	1								4
57	disturbance	4													0
58	overload	4		1											1
59	positive entropy	4													0
60	decay	4	1												1
	Group 1 Totals:		14	13	9	11	10	10	8	10	9	10	8	5	117
	Group 2 Totals:		2	3	6	3	3	4	4	3	3	2	3	2	38
	Group 3 Totals:		7	4	5	5	5	4	6	4	4	3	2	4	53
	Group 4 Totals:		1	2	1	1	1	0	0	0	0	0	0	0	6
	Overall Totals:		24	22	21	20	19	18	18	17	16	15	13	11	214

Matrix 2. GST Concept/Author Matrix Ranked Highest to Lowest

		Group	Borich 1982	McCor. 1972	Smith 1966	Gagné 1962	Dick 1985	Heinich 1985	Gagné 1987	Brans. 1976	Reigelu 1983	Briggs 1977	Gagné/ Briggs 1974	Kemp 1985	Totals:
1	system	1	1	1	1	1	1	1	1	1	1	1	1	1	12
2	learning	3	1	1	1	1	1	1	1	1	1	1	1	1	12
5	objective	1	1	1	1	1	1	1	1	1	1	1	1	1	12
3	field	1	1	1		1	1	1	1	1	1	1	1	1	11
4	isolation and interaction	1	1	1	1	1	1	1	1	1	1	1		1	11
6	process	1	1	1	1	1	1	1	1	1	1	1	1		11
7	feedback	2		1	1	1	1	1	1	1	1	1	1	1	11
8	control	2	1	1	1	1	1	1	1	1	1		1	1	11
9	communication	2	1	1	1	1	1	1	1	1	1	1	1		11
10	change	3	1	1	1	1	1	1	1	1	1	1		1	11
11	boundaries and environment	1	1	1	1	1	1	1	1	1		1	1		10
12	integration and differentiation	1	1	1	1	1	1	1	1		1		1	1	10
13	input	1	1	1	1	1	1	1		1	1	1	1		10
14	goal	3	1			1	1	1	1	1	1	1	1	1	10
15	output	1	1	1	1	1	1	1		1	1	1			9
16	product	1	1	1		1	1	1		1	1	1			8
17	growth	3	1	1	1	1	1	1	1	1					8
18	adaptation	3	1	1	1		1		1		1			1	7
19	subsystem	1	1	1		1			1			1			5
20	interdependence and independence	1	1	1						1			1		4
21	dynamism and dynamics	3	1		1	1			1						4
22	stress	4		1	1	1	1								4
23	open and closed systems	1	1	1	1										3
24	repair and reproduction	2			1			1	1						3
25	orders of interaction	1	1												1
26	equilibrium	2			1										1
27	homeostasis and self-regulation	2			1										1
28	isomorphism	3	1												1
29	overload	4		1											1
30	decay	4	1												1
31	organismic and non-organismic systems	1													0
32	subsystems (general purpose)	1													0
33	subsystem (special purpose)	1													0
34	state-determined system	1													0
35	state	1													0
36	equifinality	1													0
37	centralization and decentralization	1													0
38	centralized system	1													0
39	leading part	1													0
40	stability	2													0
41	ultrastable system	2													0
42	multistable system	2													0
43	stable vs. unstable equilibrium	2													0
44	negative feedback	2													0
45	positive feedback	2													0
46	goal-seeking feedback	2													0
47	goal-changing feedback	2													0
48	amplification feedback	2													0
49	steady-state maintenance	2													0
50	negative entropy	2													0
51	plasticity	3													0
52	elasticity	3													0
53	simple growth	3													0
54	population growth	3													0
55	structural growth	3													0
56	reversible change	3													0
57	irreversible change	3													0
58	teleology	3													0
59	disturbance	4													0
60	positive entropy	4													0
	Totals:		24	22	21	20	19	18	18	17	16	15	13	11	214

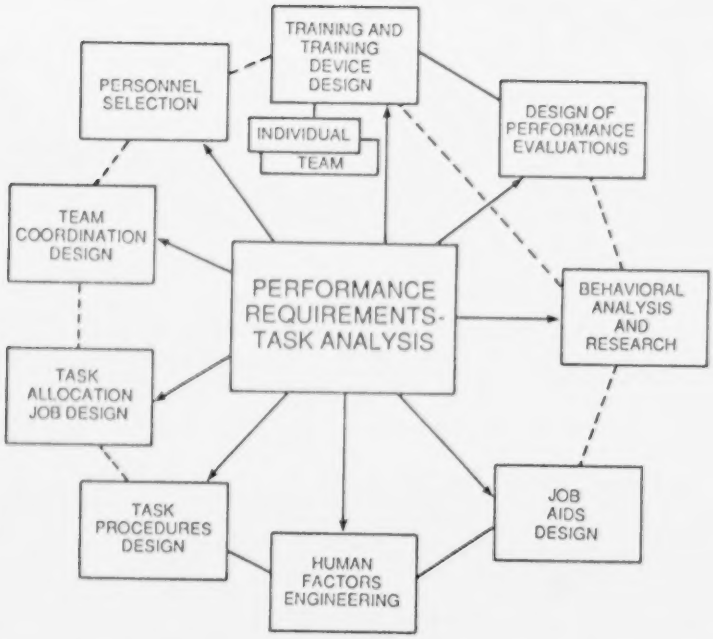

Figure 1. An early conceptualization of the systems approach to human resources development and training (from Branson & Grow, 1987).

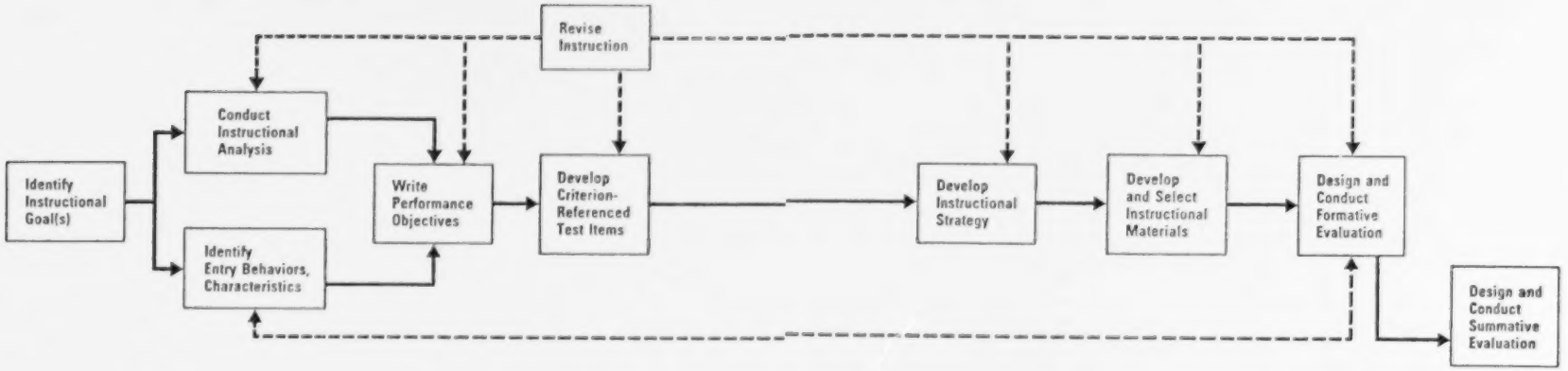

Figure 2. The Dick and Carey systems approach model for designing instruction (from Dick & Carey, 1985).

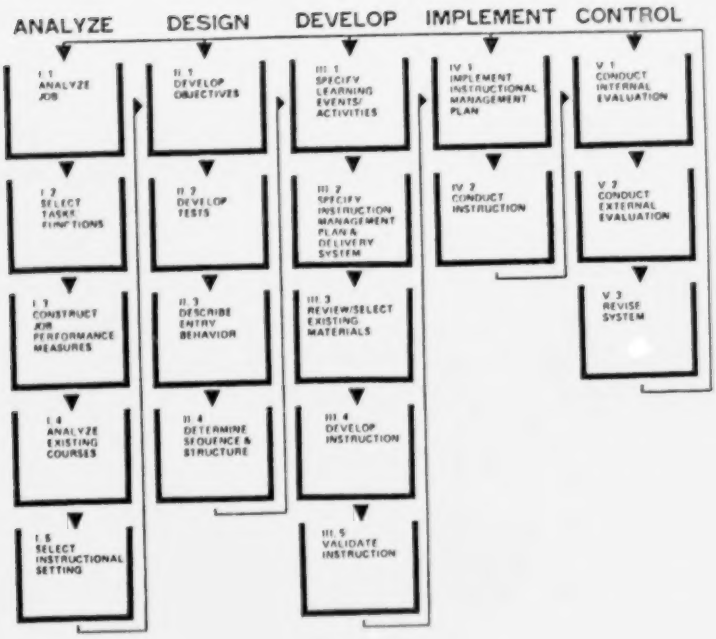
ANALYZE
DESIGN
DEVELOP
IMPLEMENT
CONTROL
I. 1 ANALYZE JOB
I. 2 SELECT TASKS FOR FUNCTIONS
I. 3 CONSTRUCT JOB PERFORMANCE MEASURES
I. 4 ANALYZE EXISTING COURSES
I. 5 SELECT INSTRUCTIONAL SETTING
II. 1 DEVELOP OBJECTIVES
II. 2 DEVELOP TESTS
II. 3 DESCRIBE ENTRY BEHAVIOR
II. 4 DETERMINE SEQUENCE & STRUCTURE
III. 1 SPECIFY LEARNING EVENTS/ ACTIVITIES
III. 2 SPECIFY INSTRUCTION MANAGEMENT PLAN & DELIVERY SYSTEM
III. 3 REVIEW/SELECT EXISTING MATERIALS
III. 4 DEVELOP INSTRUCTION
III. 5 VALIDATE INSTRUCTION
IV. 1 IMPLEMENT INSTRUCTIONAL MANAGEMENT PLAN
IV. 2 CONDUCT INSTRUCTION
V. 1 CONDUCT INTERNAL EVALUATION
V. 2 CONDUCT EXTERNAL EVALUATION
V. 3 REVISE SYSTEM

Figure 3. The model of interservice procedures for instructional systems development (IPISD) (From Branson & Grow, 1987).

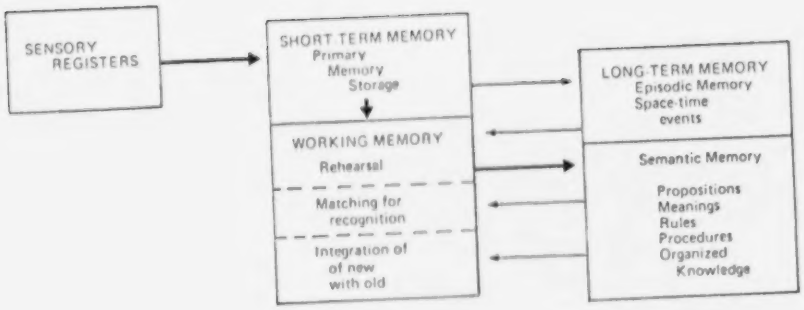

Figure 4. Information flow in short- and long-term memory systems (From Gagné & Glaser, 1987).

Institutional Level (School system)

Purpose: To provide facilities and resources in support of the operating systems

Key Entity: Needs, requirements of the environment and the operating systems

Primary Decision-Maker: Managers, policymakers, boards

System Input: Societal needs and values, resource requirements of the instructional system, financial resources available

System Output: General educational goals, allocation of resources in support of operating systems, and policies regulating the use of resources

Administrative Level (System-wide administration)

Purpose: Support the instructional level, given a set of policies and resources.

Key Entity: Formalized information relevant to societal expectations, insitutional policies, and instructional-system needs.

Primary Decision-Maker: System-wide administrators, school principals

System Input: The output of the institutional level and requirements of the instructional system level

System Output: Policies regulating the use of resources and specifying educational requirements

Instructional Level (Instructional systems)

Purpose: To provide instruction to students

Key Entity: Instructional goals and objectives

Primary Decision-Maker: Instructional-systems manager and teacher

System Input: The output of the administration level, instructional aims and design, staff, facilities, students

System Output: Instructional systems, instructional arrangements, instructional delivery-systems, resources.

Learning Experience Level (Classes or groups of students)

Purpose: To optimize instructional arrangements

Key Entity: Instruction

Primary Decision-Maker: Teacher

System Input: The output of the instructional level and implemention plans geared to specific instructional arrangements

System Output: Students who can perform on specified instructional objectives

Figure 5. Banathy's description of an educational systems complex (From Banathy, 1987).

Inputs	Processes
instructors	teaching
learners	learning
existing goals and objectives	studying
existing needs	instructing
entry skills, knowledges, and abilities	reciting
motivation	interacting
expectations	planning
buildings	managing
attributions	presenting
equipment	testing
facilities	writing
laws	computing
policies	lecturing
administrators	

Figure 6. Some examples of inputs and processes in education (From Kaufman & Thiagarajan, 1987).

Element	*Examples*	*Efforts/Results*
Inputs (raw materials)	ingredients, existing human and physical resources, policies, values, state-of-the-world	Organizational Effort
Processes (how-to-do-its)	means, methods, procedures, techniques, manufacturing, organizational development	Organizational Effort
Products (en route results)	services delivered, reports completed, skills required, production quota met	Organizational Results
Outputs (aggregated products delivered to society)	delivered automobiles, delivered computer systems, patients discharged	Organizational Results
Outcomes (effects in and for society	profit, off welfare rolls, having financial credit, contributing to self and society, customer satisfaction	Societal Impact (the External Element)

Figure 7. Kaufman's organizational elements model showing examples and their relation to organizational and societal results (From Kaufman & Thiagarajan, 1987).

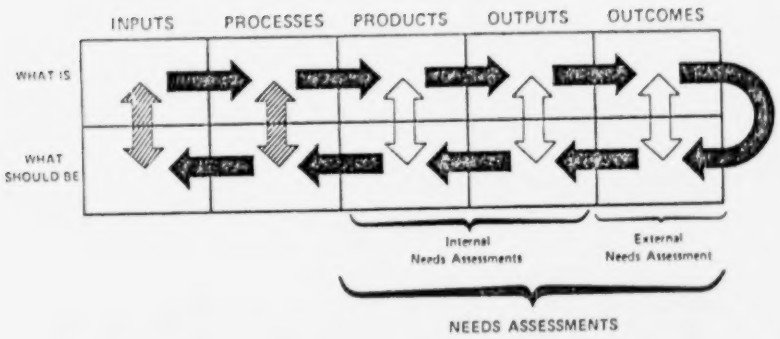

Figure 8. The organizational elements model in its bi-level form showing gap between "what is" and "what should be" (From Kaufman & Thiagarajan, 1987).